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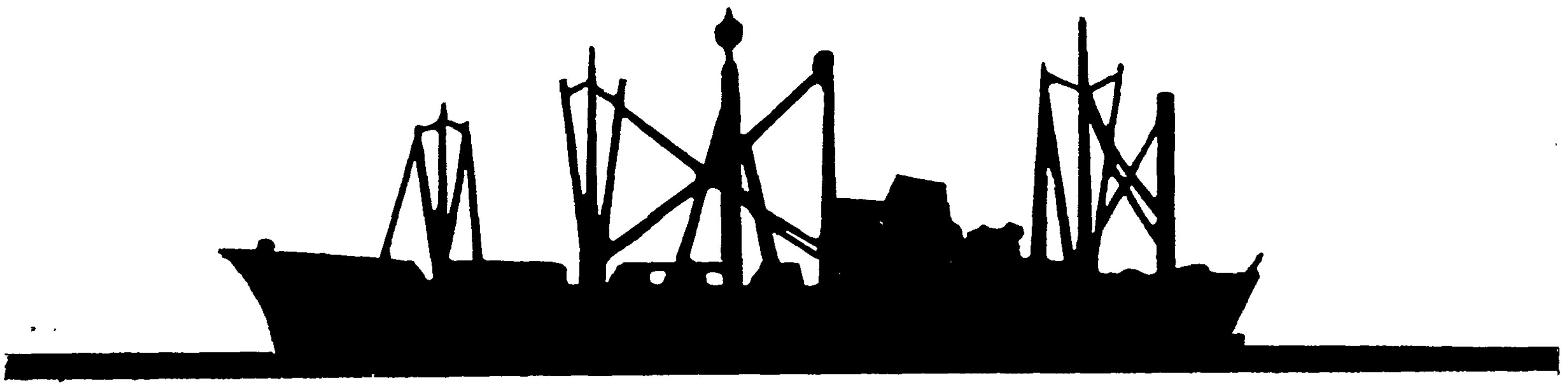

INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

I R E A P S

KEYNOTE ADDRESS

CONSIDERATIONS REGARDING IMPROVED PRODUCTIVITY BASED UPON EXPERIENCE OF SERIES PRODUCTION OF MERCHANT SHIPS

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ABSTRACT

In 1960 B&W Shipyard commissioned new yard facilities introducing new building methods with large blocks (modules, sections) assembled in the building dock by gantry cranes. To ensure effective operation of such facilities, computer based sophisticated planning and control systems were developed. The anticipated improvement in production efficiency of the new system remained, however, for the first decade of operation, as it was with traditional shipbuilding. Upon thorough analysis of the situation the yard management was forced to acknowledge that the excessive complexity of systems applied had made the understanding of fundamental parameters for successful planning and control of new systems ambiguous.

Accepting that shipbuilding is only as complicated as one chooses to make it, the yard started to simplify all phases of the shipbuilding processes. Discarding complicated systems and for one off production, efforts were centered on series production of ships to improve productivity sampling whatever Japanese impulses were considered adaptable to the yard.

Over a two-year period the yard more than doubled the throughput while at the same time reducing man-hours per ship by close to 50%. Specializing in Panamax bulk carriers at peak efficiency, the yard launched one vessel from its building dock every 28 working days. Some basic considerations are covered as to how productivity can be achieved by relying more on common sense than on complicated computer systems.

1. INTRODUCTION

Except for government provision offering customer financing on OECD terms, Danish shipyards receive no subsidies and must compete in the open market against efficient Far Eastern yards with a low labour cost or against less efficient European yards, where pricing is governed more by the need of securing employment or hard Western currency than by sound business considerations.

In meeting this competition the policy of Burmeister & Wain Shipyard in recent years has been to concentrate on series production, even at sales prices lower than may be obtained for more specialized tailored "one off" products. The yard has found advantages of series production sufficient to compensate for lower price per unit, providing market conditions justify expectations of sales.

In the sixties Burmeister & Wain had a somewhat limited success in obtaining orders for larger series production, except for 25 fish factory ships (Figure 1) built in batches in between other production.

In the seventies the yard, however, succeeded in obtaining orders for 23 bulk carriers of each 52,000 dwt (BC 50), followed by 14 Panamax bulk carriers of 60,000 dwt (BC60) built in succession in the period between 1975 and 1977. Figure 1 shows the series as obtained in the period 1955-77 which on a percentage basis compared favourably even in accordance with Japanese records Figure 2.

Burmeister & Wain Shipyard is presently engaged in the production of further 18 of Panamax size (BC60E2), similar to the previous series except for improved fuel efficiency.

*

In the fifties Burmeister & Wain Shipyard conceived and implemented the system of gantry crane assembly of large steel blocks in a building dock at a considerable cost. Productivity, however, did not improve for major reasons of product mix and newly adopted systems that made recognition of rudimentary factors of performance somewhat ambiguous.

After a decade where yard productivity barely surpassed past performance at old berths, losses accumulated as competition grew harder.

Eventually, as yard management was forced to acknowledge that the previous approach was not applicable, a policy was adopted based upon series production and a simplified approach to planning with particular priority to the objective of increasing throughput maintaining labour force at approximate constant level.

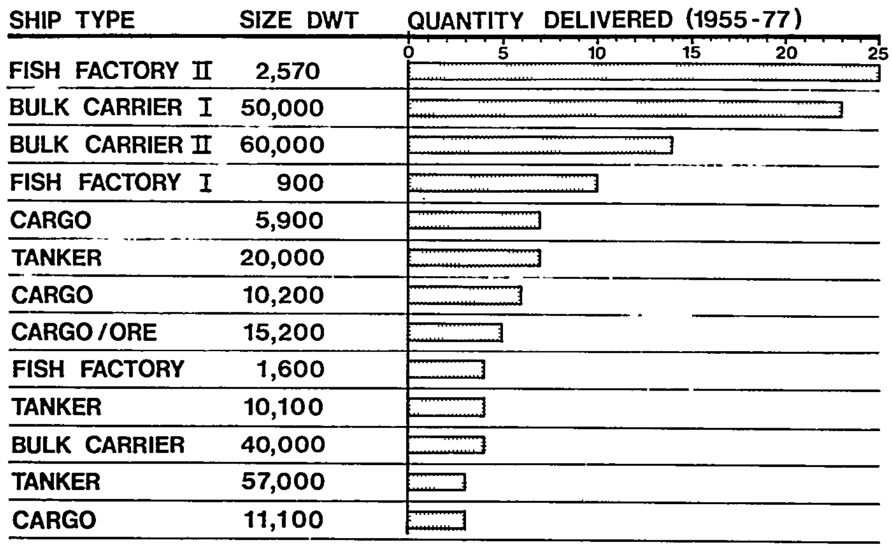


FIG. 1 SERIES PRODUCED 1955-77

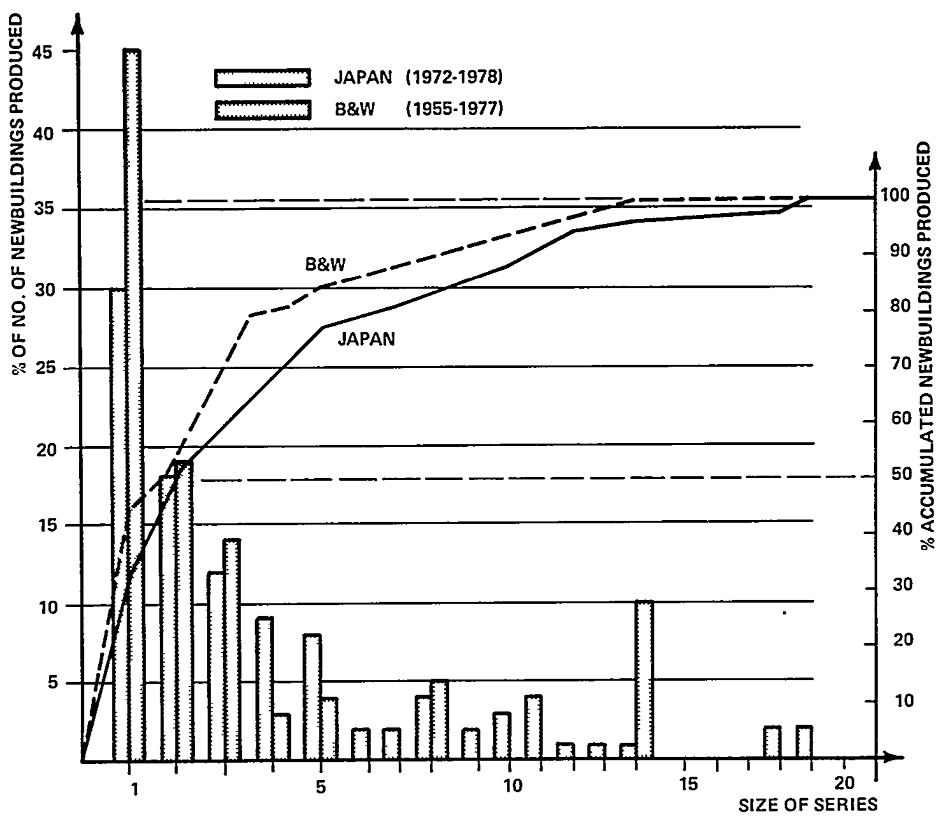


FIG. 2 COMPARISON OF SERIES PRODUCTION

In the years 1972 to 1976 the production of bulk carriers rose from 3.5 to 7.5 per year equivalent to an increase in steel output from 30,000 to 78,000 tons per year (Figure 3).

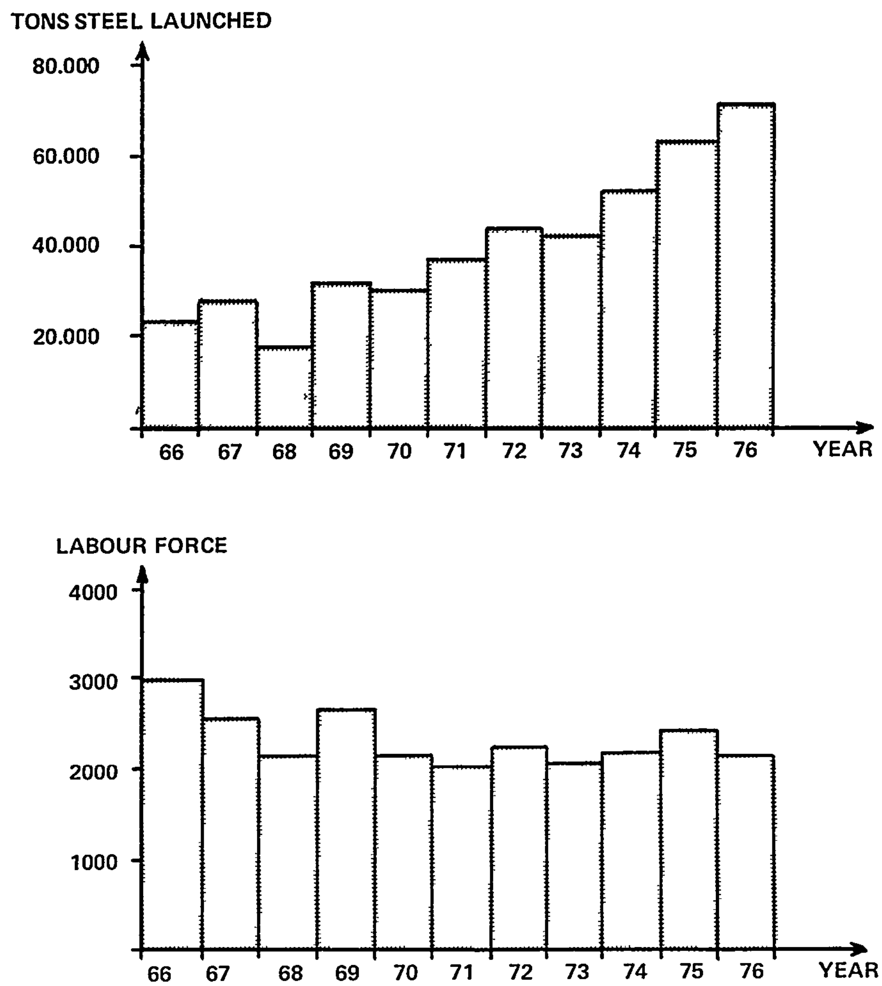


FIG. 3 **LABOUR FORCE AND TONS STEEL LAUNCHED AT THE YARD IN PERIOD 1966 TO 1977**

The topic of today is to give some factors as found essential in achieving this improvement.

2. PRODUCTIVITY

By definition productivity for a specified ship complexity can only be improved by increasing output or by reducing manhours.

Reduction of manhours thus becomes an objective only obtainable by reduction in work force, if production rate is to be maintained. It is somewhat astonishing in declining markets to register arguments from yards requesting government grants for investments and support of operating costs for the contradictory purpose of improving efficiency while maintaining employment.

Improvement of productivity may be obtained through parameters summarized as follows:

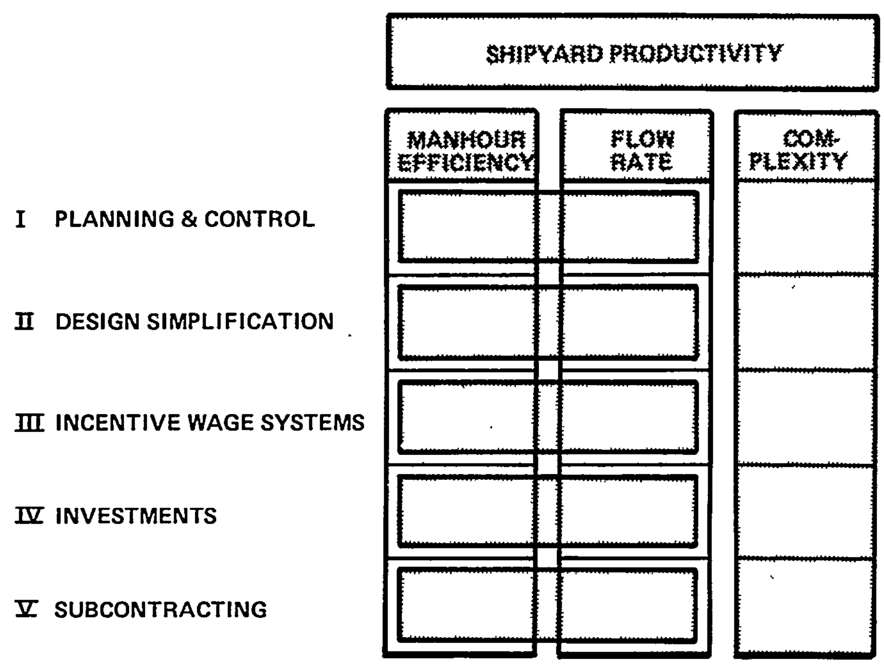
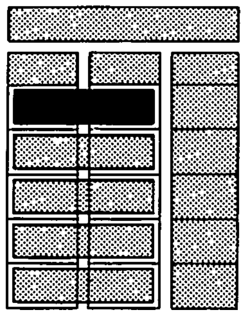


FIG. 4

The complexity of work content can be difficult to define, and is hopefully reflected in a contractual price allowance for increased value.

As the topic of consideration is productivity in series production, complexity becomes fixed and factors of productivity can better be recognized when evaluating records of past performance.

3. PLANNING AND CONTROL



Reduction in manhours is by nature the objective of every shipyard management. For series production this reduction is expected as repetitive effect of experience takes place.

Figure 5 shows the outfitting manhours on the comparatively complex fish factory ships. These ships were built in between 29 other cargo ships, tankers and bulk carriers ranging in size from 10 to 80,000 dwt. The series effect on these complicated ships is conspicuously large due to complexity of work content, insufficient planning and preparation and effects of batch production until the point where employees are so familiarized with the product that efficiency is maintained even with mixed production.

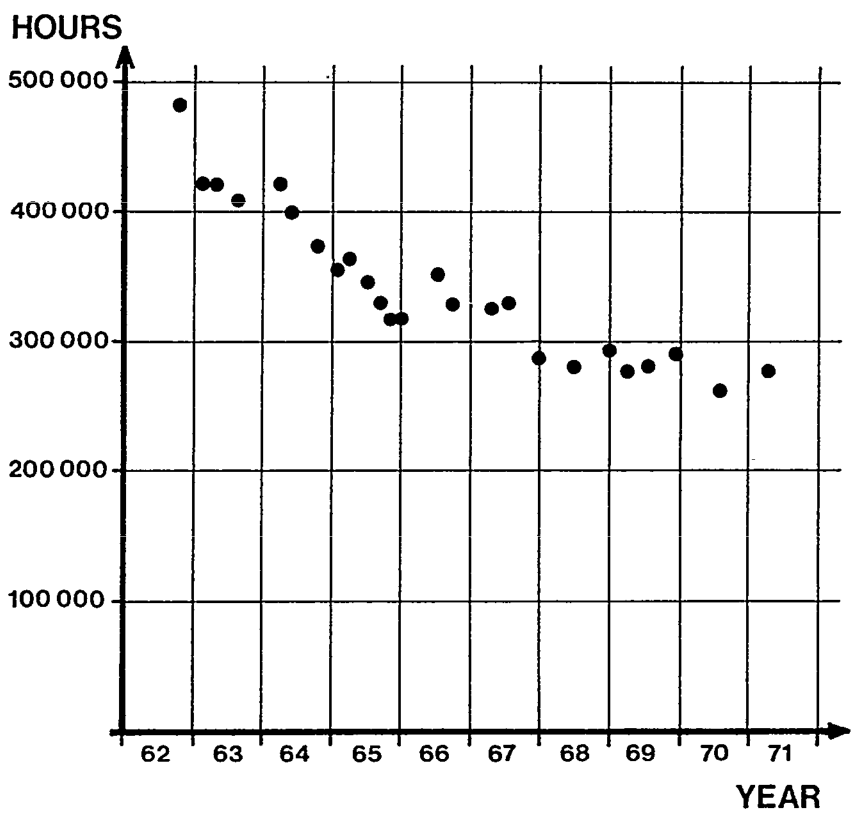


FIG. 5 OUTFITTING HOURS FOR FISH FACTORY SHIPS

Manhours for the bulk carriers are shown in Figure 6. The first four vessels built almost in succession (group A) showed remarkable improvement in efficiency, subsequent sisterships (group B), built in between other production, showed considerable increase in manhours. Evaluation of performance in building these ships indicated allocation of labour had little effect on steel output, as registered manhours were dependent only on number of people employed (Figure 7). Quite evidently, obstructions existed that could not be overcome by manpower alone.

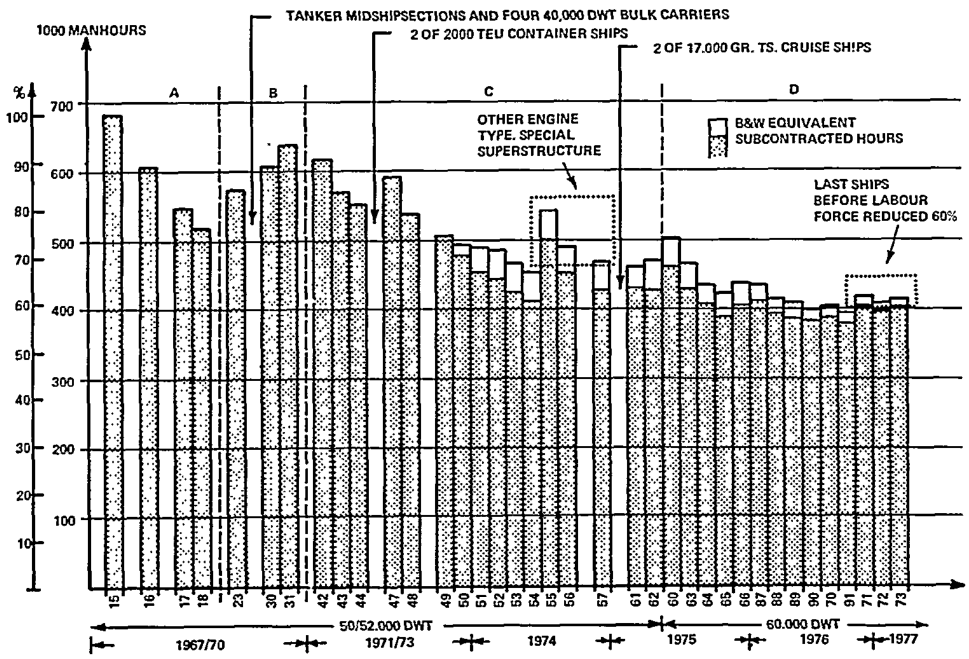


FIG. 6 DIRECT MANHOURS FOR BULK CARRIERS BUILT IN SERIES AT B&W SHIPYARD IN THE PERIOD 1967 TO 1977

In analyzing this problem in steel production a flow chart was made registering the movement of more than 48,000 pieces of steel (Figure 8). Production targets were thereupon subdivided workshopwise into items produced within the required period of time. Planning and follow up was based upon parameters best correlated to work content, (schematically shown in Figure 9), and previously registered manhours and the systems based thereupon were more or less disregarded.

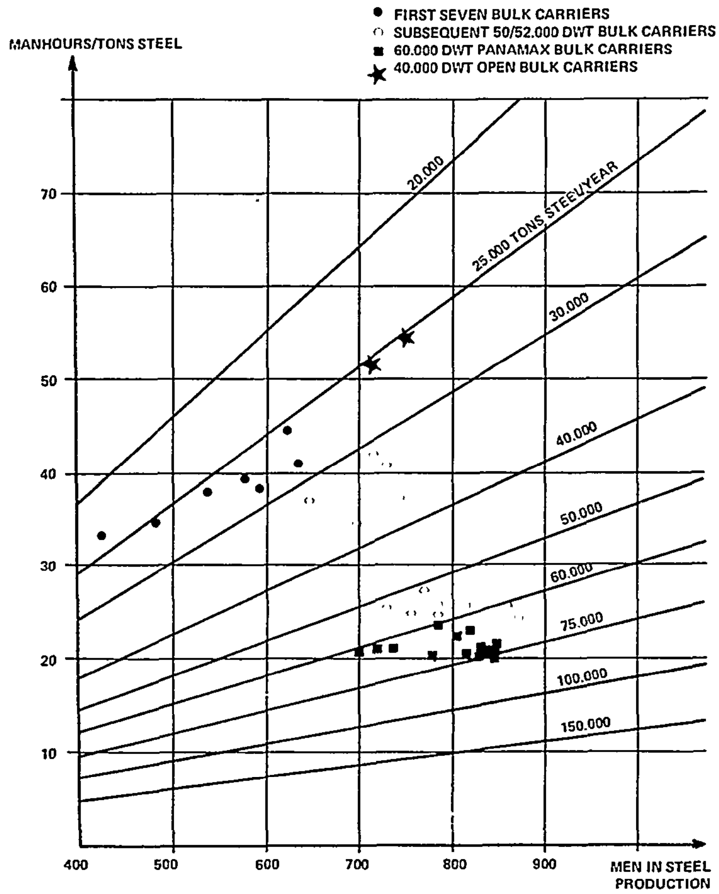


FIG. 7 RELATION BETWEEN MANHOURS/TS, STEEL OUTPUT AND WORKFORCE FOR BULK CARRIERS

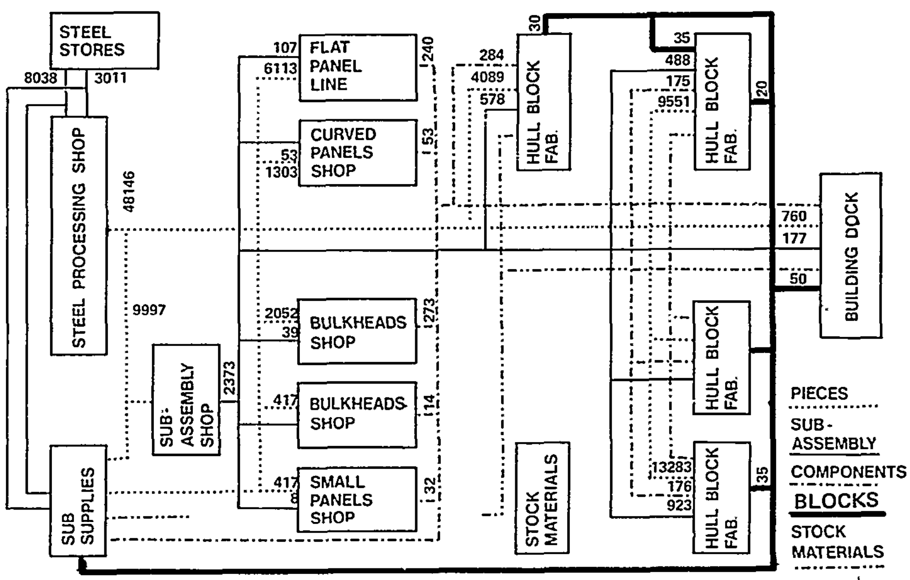


FIG. 8 MATERIAL FLOW CHART

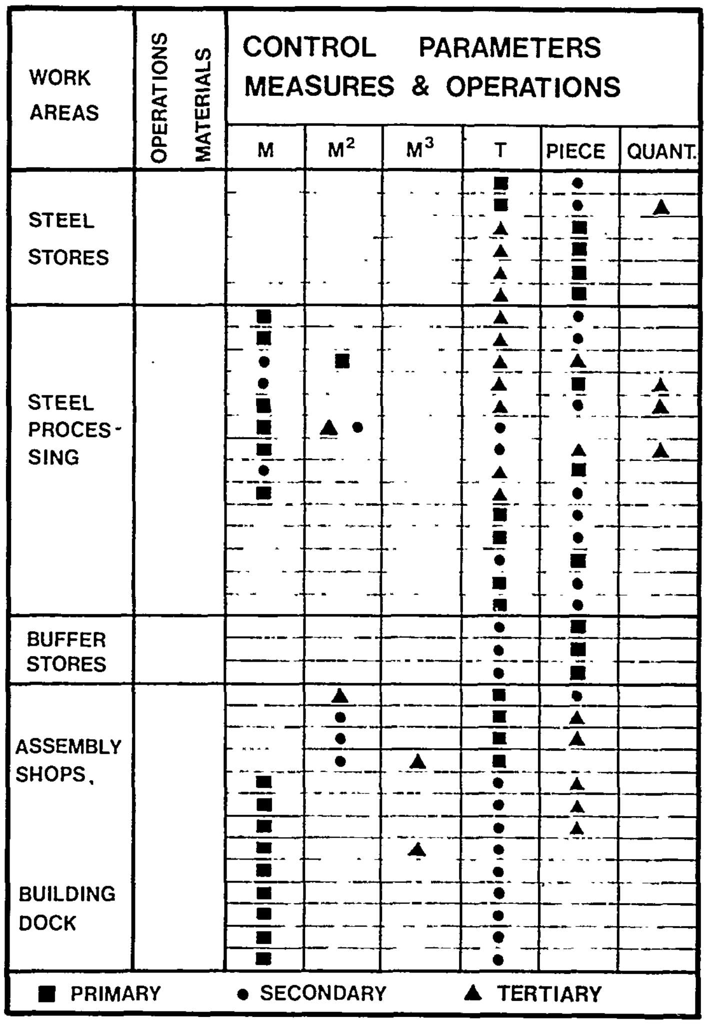


FIG. 9 PRODUCT FLOW PARAMETERS

Concluding these evaluations yard status as per 1972/73 is shown in Figure 10. The production capacity was restricted to 4 ships per year and the future target of 7 1/2 ships per year could be met only by the building dock.

REQUIRED CAPACITY = 7,6 SHIPS / YEAR

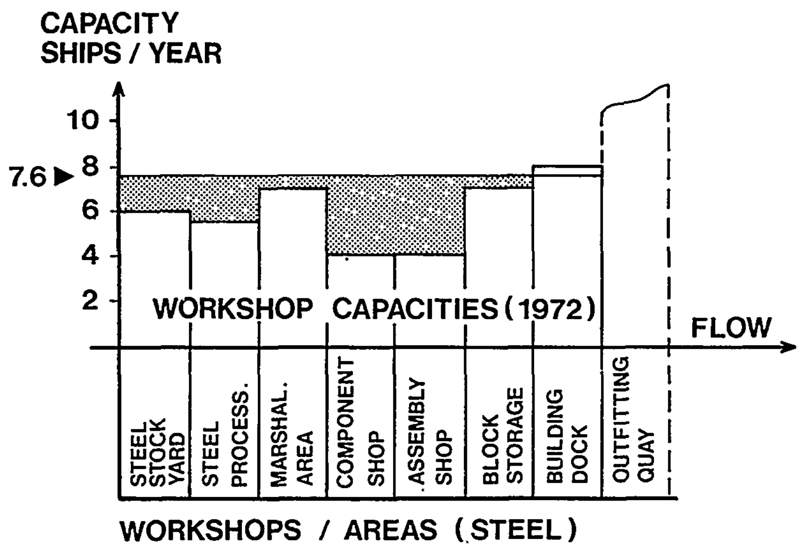


FIG. 10 CAPACITY PROBLEM BOTTLENECK

Production complexity for the bulk carriers in terms of manhours, production time and production area required is shown in Figure 11. As may be foreseen the fore and aft part is more labour intensive and requires longer production time, more crane coverage, supply service etc., than the parallel midship. This longer production time requires more space.

Cycle period is to be reduced, then average steel block weight and area under crane coverage must increase to facilitate increased throughput (as shown in Figure 12). The load on facilities can be levelled by dispersing work content to other and earlier stages. As shown by module production, Figure 13, or by tandem production, Figure 14, where labour intensive part of engine room for next ship is built in a separate location at the same time and building period as the ship to be launched.

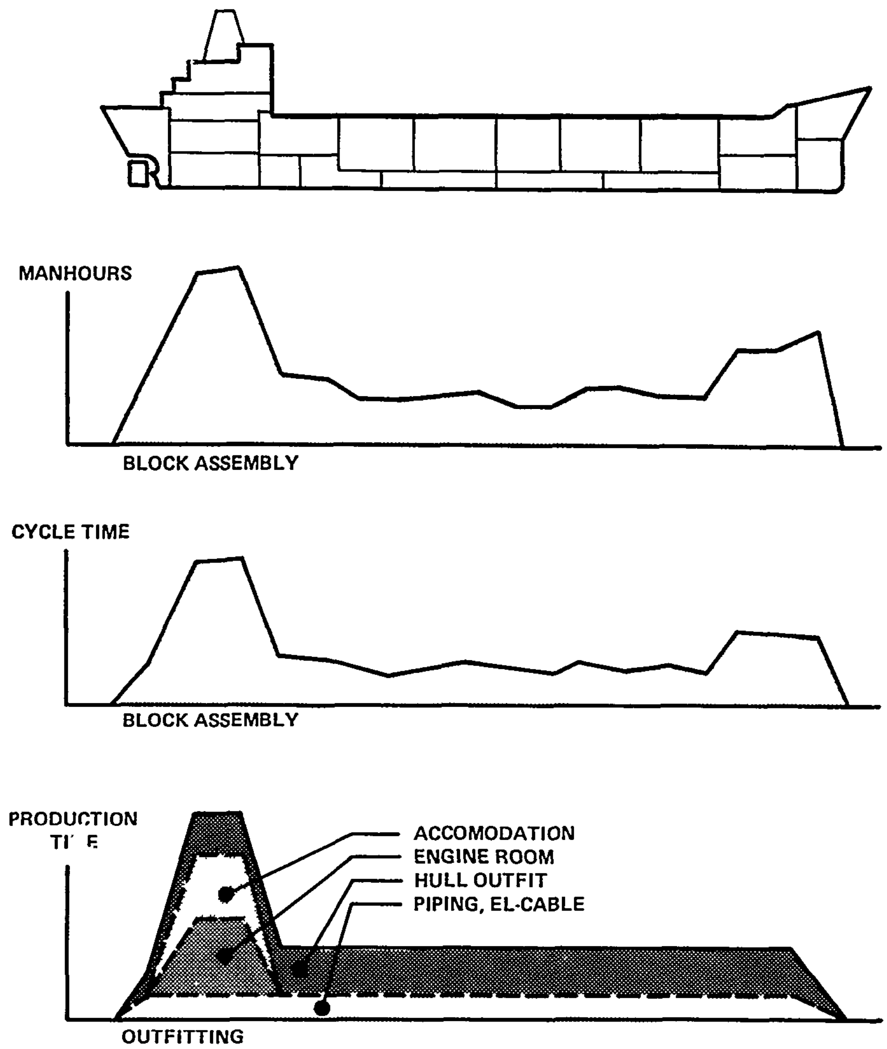


FIG. 11 LOAD DISTRIBUTION FOR BC50

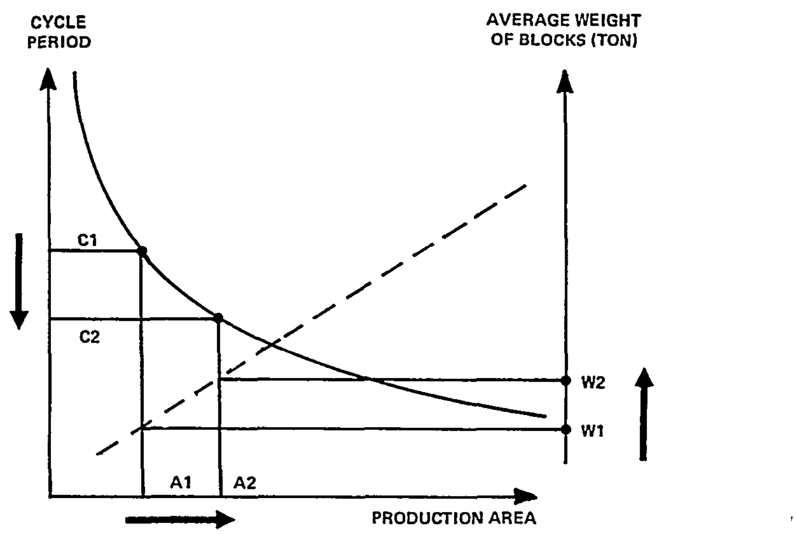
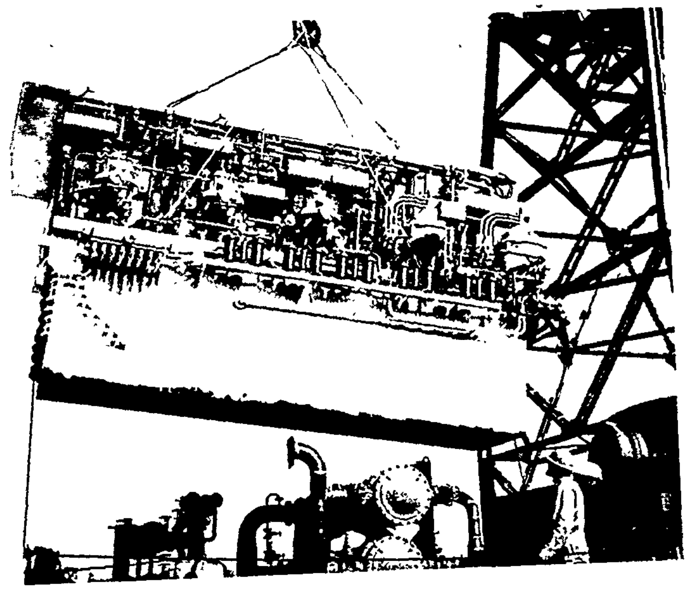


FIG. 12 AREA/ACTIVITY DURATION/WEIGHT OF BLOCK



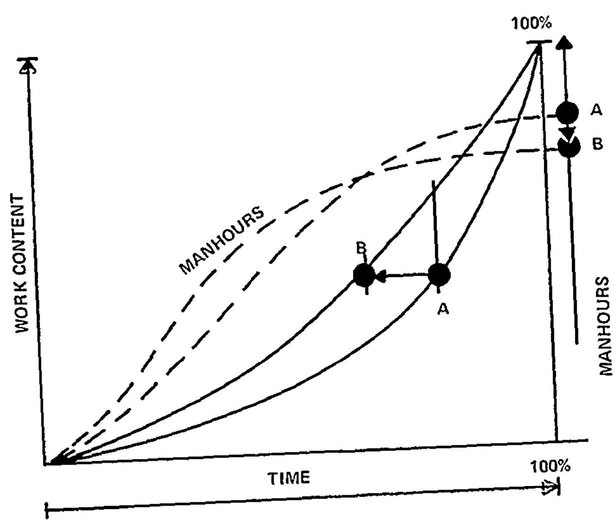
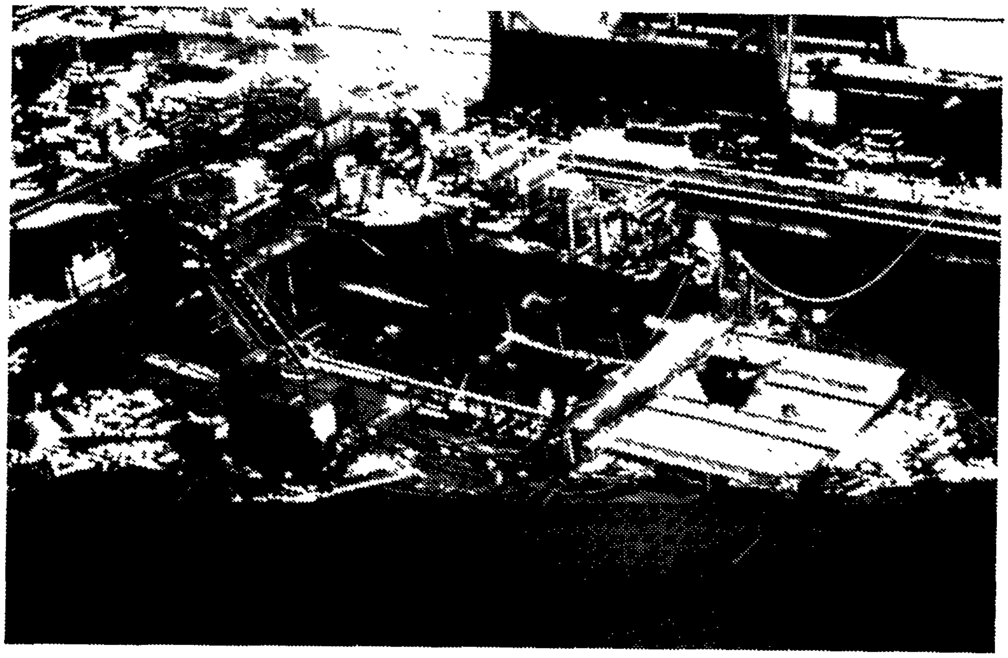


FIG. 13 MODULE PRODUCTION



ENGINE ROOM BLOCK IN DRY DOCK (STEP 2)

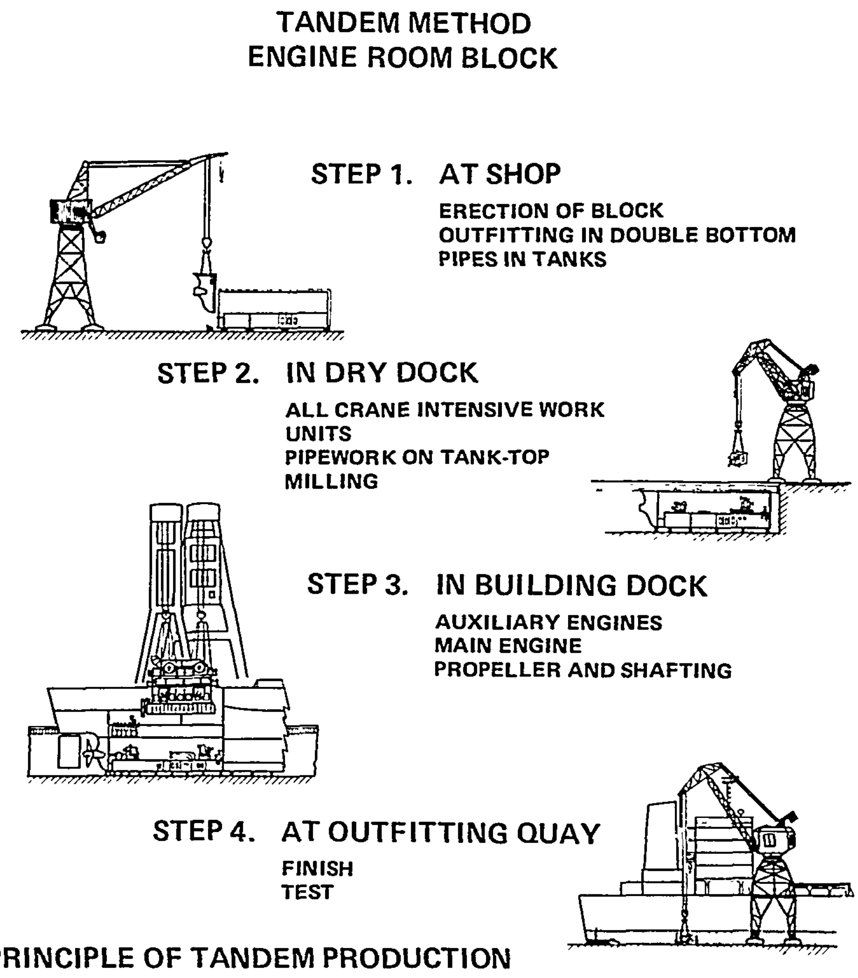
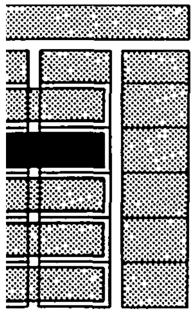


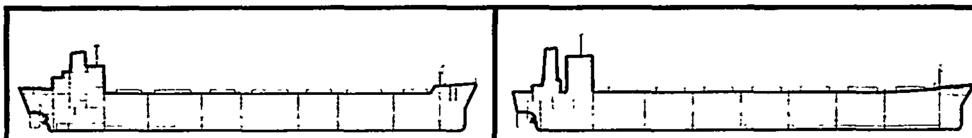
FIG. 14 PRINCIPLE OF TANDEM PRODUCTION

4. DESIGN SIMPLIFICATION



It is our experience that the greatest possibilities for productivity improvement are to be found at the design stage, not only at the time of making the working drawings, but also at the earliest stage of specifying the product. We were successful in the marketing of our 52,000 dwt bulk carrier and we could have sold many more. From our analysis we recognized, however, the necessity of simplifying the product and making it more suitable for production while maintaining or improving the service operating features of the ships.

Figure 15 indicates how the ships were simplified by removing forecastle and poop, box shaping superstructure, modulizing engine room, reducing number of blocks, standardizing hold and hatch sizes as well as double bottom height.



52.000 DWT	
STEEL WEIGHT	7,900 TONS
NO. OF STEEL PLATES	3,200
NO. OF SHAPES	8,000
NO. OF HULL PIECES	51,000
WELD LENGTH	155 MILES
PIPE LENGTH	24 MILES
ELECTRICAL CABLES	25 MILES

60.000 DWT	
STEEL WEIGHT	9,000 TONS
NO. OF STEEL PLATES	2,600
NO. OF SHAPES	4,000
NO. OF HULL PIECES	35,000
WELD LENGTH	125 MILES
PIPE LENGTH	16 MILES
ELECTRICAL CABLES	26 MILES

FIG. 15 SIMPLIFICATION OF BULK CARRIER DESIGN

Every part of the ship was redesigned with the purpose of making work easier even if steel weight had to be slightly increased. Figure 16 shows an example as to how such simplifications can be made on scantlings in double bottom, hopper and topwing tanks.

For many years Burmeister & Wain has possessed a computer system for developing single curvature ship lines and straight expansion of approximately 95% of hull surface. The hull form, somewhat untraditional from a naval architectural point of view, provides great simplification in workshop production, while maintaining excellent hydrodynamic characteristics.

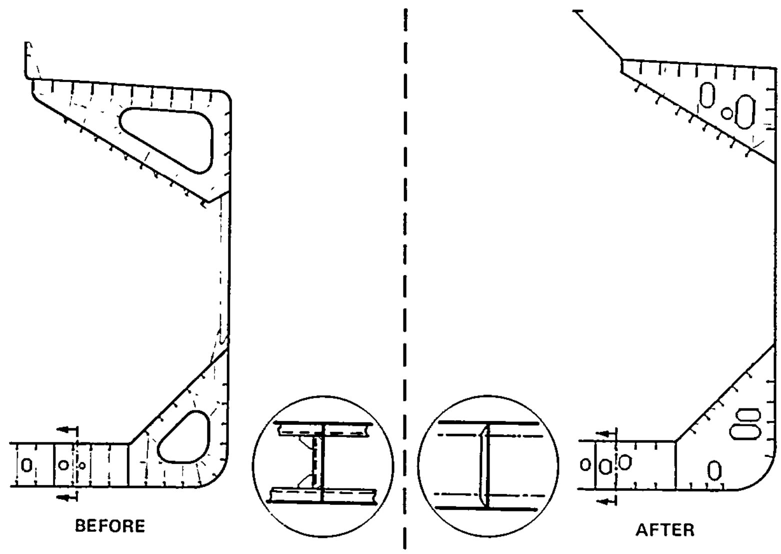
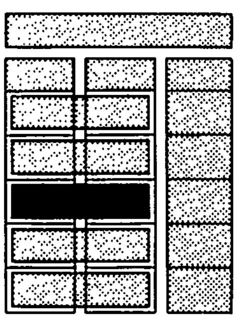


FIG. 16 MIDSHIP SECTION

5. INCENTIVE WAGE SYSTEMS



Burmeister & Wain Shipyard has for many years operated with incentive wage systems for blue collar workers. The ratio of fixed part of salary to bonus was in general 4:1 and the gross salary obtained on one ship was considered basis upon which bonus for next ship was to be negotiated (see Figure 17).

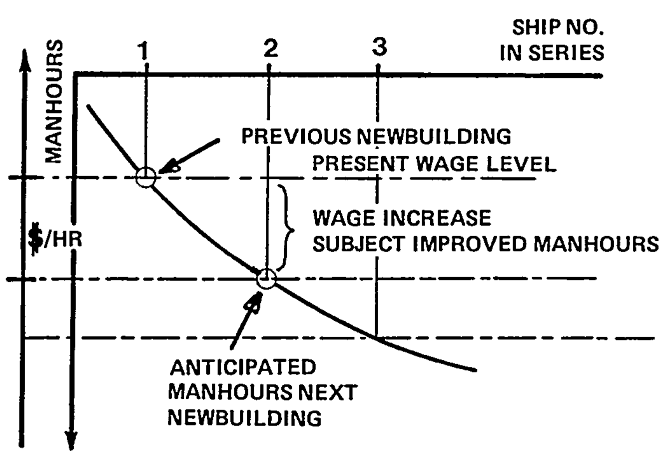


FIG. 17 PRINCIPLE OF WAGE AGREEMENT PREVIOUS SERIES OF BC50 AND BC60

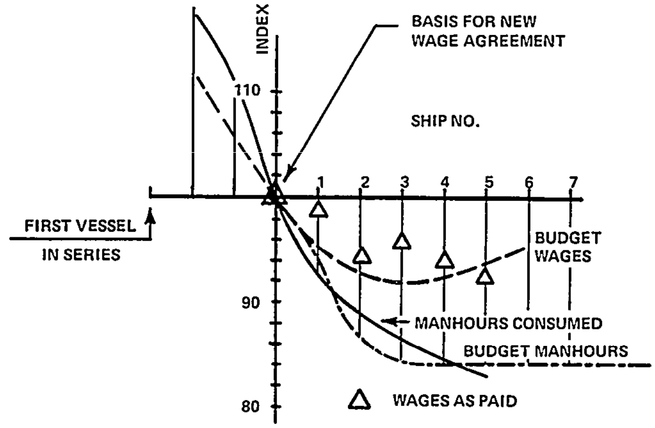
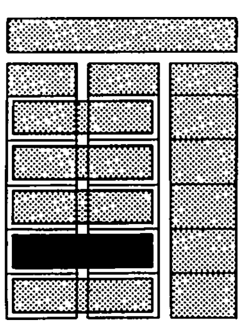


FIG. 18 FIRST YEAR RESULT OF WAGE AGREEMENT PRESENT SERIES

Incentive wage system alone will not improve productivity, but the system of having a carrot in front of the worker in our opinion makes him more benevolent in adopting systems of improvement. Admittedly it is difficult to adjust the distance as well as size and quality of the carrot. The administration of these wage systems is complicated, particularly at yards such as ours with 14 shop stewards. The effect of incentive wage systems on efficiency cannot be properly evaluated, but contrary to most continental yards we believe in the system, particularly after registering Swedish experience of 20-25% increase of manhours following the abandoning for political reasons of incentive wage systems.

In our present series of 18 ships we have succeeded in obtaining fixed agreement for 15 ships. Although somewhat premature for conclusions our results to date are promising (see Figure 18).

6. INVESTMENTS



Since the commissioning of the new facilities our yard has spent comparatively small amounts on investments (Figure 19) for the reason that savings in production costs could not justify financial costs at the high Danish interest rate. In solving our bottleneck problem we were, however, forced to increase our crane coverage in numbers more than lifting capacity to serve the exponential demand when increasing flow capacity.

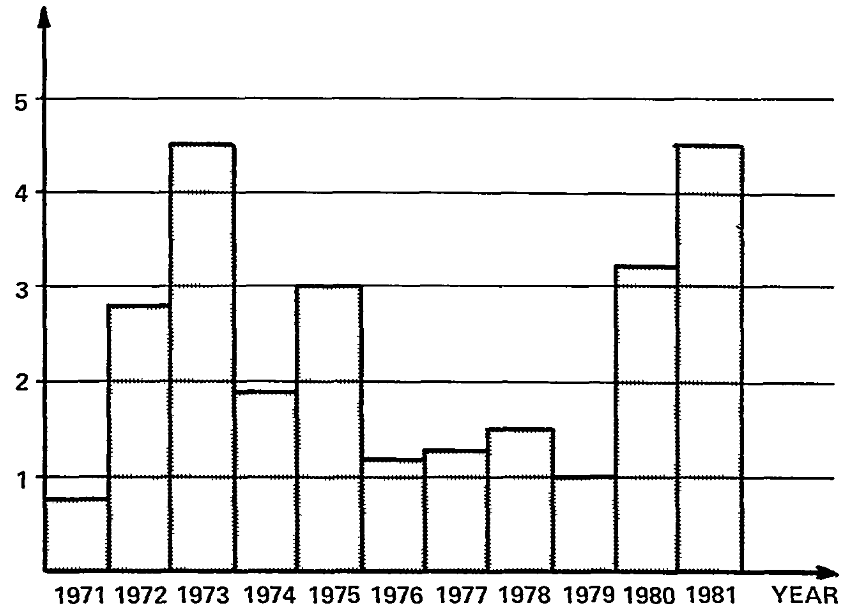


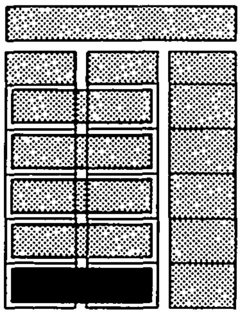
FIG. 19 INVESTMENT % OF TURNOVER

Adequately covered with the basic prerequisites of space and crane coverage, our investments policy has since been limited to purchase of minor equipment (such as automatic welding machines) and to development of new software systems. We do not believe in investments in sophisticated numerically controlled equipment for the early steel production stages, such as plate storage handling and plate and profile cutting workshops, for the simple reason that in a production process where 70% of the manhours are consumed in assembly halls and building dock and 20% in subassembly, limited effect on total picture can be obtained by substantial investments on reduction of the last 10% of manhours consumed in the plate handling and cutting process.

Further it has been seen in the past that such investments made to reduce manhours actually create new production flow obstructions. A Scandinavian yard of distinction invested in an automatic panel frame fitting machine that in 15 minutes with great accuracy and three string welding fitted the frames to the plates, only to discover they had created a bottleneck restricting yard output to 15 minutes per frame. The problem was solved by creating additional area outside where fitting was done by traditional gravity welding. Incidentally, Labour cost maintaining this machine surpassed labour saved in the new work process.

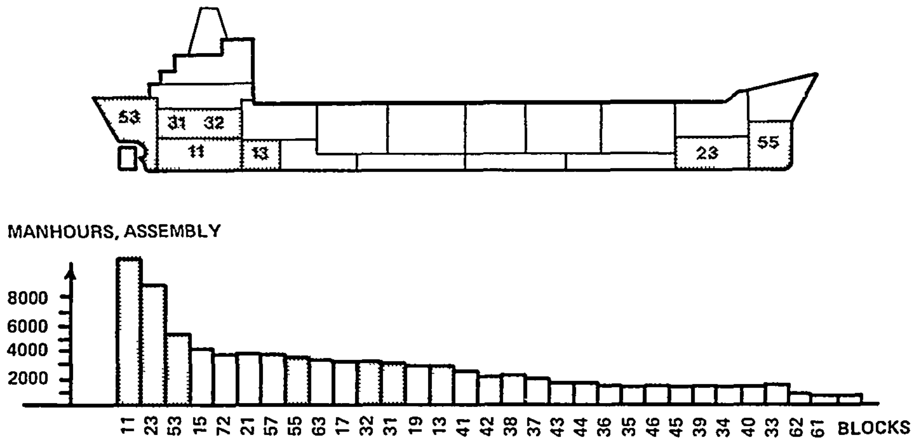
Our investment policy might be seen in respect to our building program and might indeed be different if we worked with different products and product mix.

7. SUBCONTRACTING



Subcontracting is an activity frequently adopted in the Western hemisphere. Some Japanese shipyards consider shipbuilding to comprise only two basic activities: steel production and logistics.

Subcontracting as compared to own production is elementary in respect to evaluating cost of manhours and efficiency, but perhaps more difficult when evaluating relief on facilities and resources that can then be relocated to more suitable work.



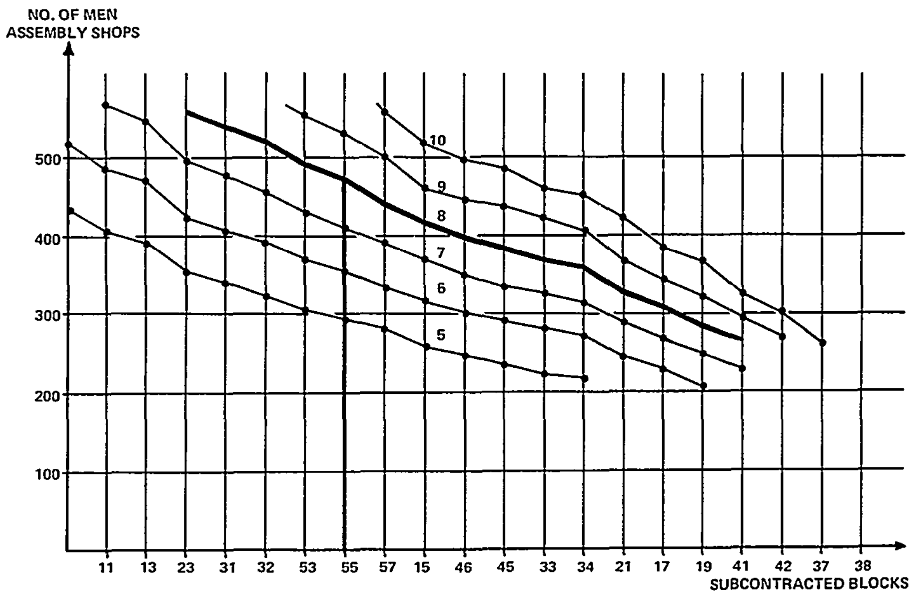


FIG. 20 & 21 **NO. OF BLOCKS SUBCONTRACTED FROM ASSEMBLY SHOPS WITH EFFECT ON PRODUCTION FLOW FROM ASSEMBLY SHOPS**

With reference to Figure 11, ship block production manhours can be split up as shown in Figure 20. By subcontracting labour intensive work which requires a heavy load on workshop facilities, e.g. block 11, resources can be allocated to easier blocks. Figure 21 indicates in theory how production flow of ships can be increased by subcontracting blocks provided of course that building dock facilities are sufficient to assemble blocks at required rate.

8. CONCLUSIONS

The result of our efforts are shown in Figure 6, Figure 7, on percentage basis Figure 22, and Figure 23.

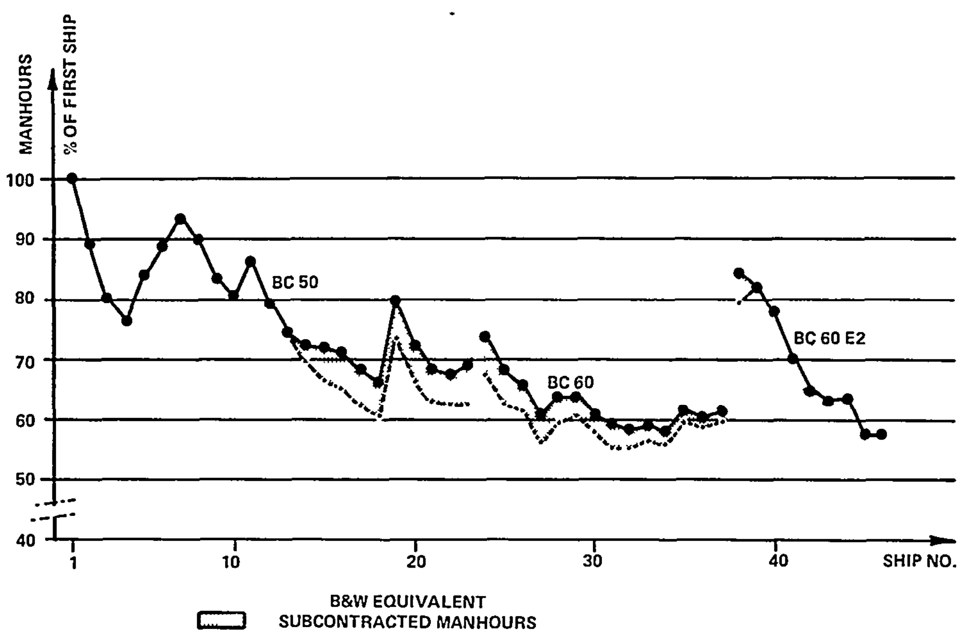


FIG. 22

When evaluating means of improving productivity particularly in respect of increasing the throughput, the cost of administration and control must be taken into consideration.

Our yard operates on a fixed price basis with no adjustments except for extra equipment and our accounting system is based on invoicing at delivery. This means that profit is turned to account only when a new building is delivered.

Our indirect costs are considered on shipyard year total only and are hopefully adequately covered by sum for contribution margin for the number of new buildings delivered that year. By increasing output, required contribution margin per newbuilding can be reduced, however, an increased production rate will require increased indirect costs (Figure 24).

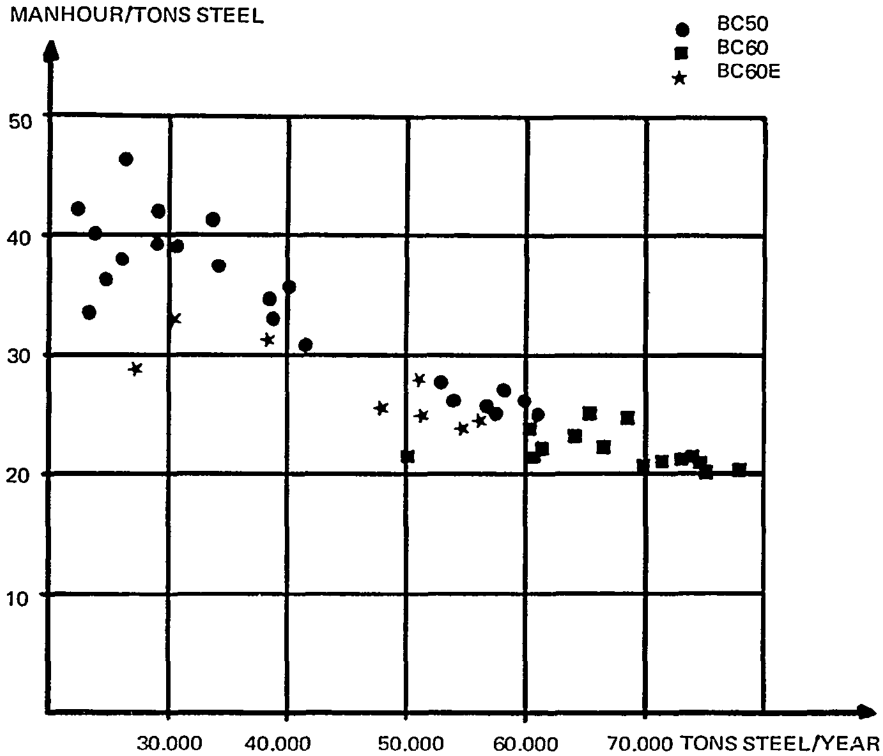


FIG. 23

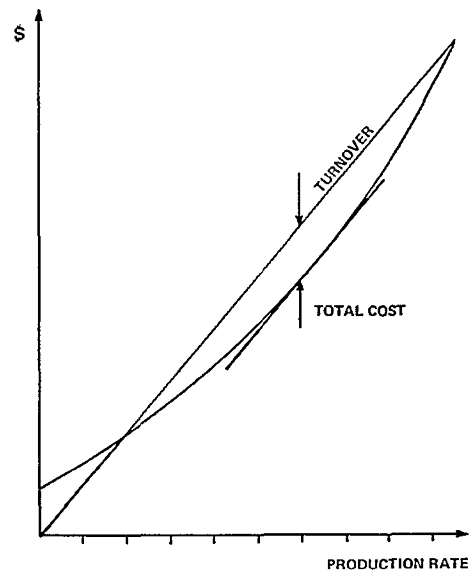


FIG. 24 RELATION COSTS/TURNOVER

At our peak production period of 1976/1 977 we were close to a production rate of one ship launched from our newbuilding dock very 25 working days, and such highly geared activity requires considerable attention to planning, follow up and quality control, both of equipment and production.

Our yard has presently geared down to a production rate of 5.4 ships per year due to market considerations and a policy aimed at limiting the sensitivity of the labour force to a fluctuating market.

Labour force and staff reduction compared to production can be summarized as:

Year	Labour Force Average		Staff*		Production Panamax/Year	
1976/77 1982	2000 ↓ 1400	30%	570 ↓ 290	49%	7.6 ↓ 5.4	29%

* Excluding department of Shipbuilding Services providing ship designs to other yards around the world.

Having virtually been at a stand-still in 1979 with only 950 workers employed, it has meant some difficulties to get the yard restarted even to the lower production target. Our present efficiency is approximately as previously attained, but we have experienced that this efficiency is more difficult to achieve at a lower production rate. This, however, is a topic we might revert to in the future, when we have finished our present series.

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